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HYDROGEN POWER PARK BUSINESS OPPORTUNITIES CONCEPT PROJECT

**Design, Analysis
& Demonstration**

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Arizona Public Service
April 2004**



- ◆ **To Identify Component Options For Off-Grid and Grid-Connected Power Park Systems**
- ◆ **To Develop Models For Off-Grid and Grid-Connected Power Park Systems**
- ◆ **To Evaluate The Performance Of Model Power Parks Through Testing Of Components**
- ◆ **To Identify Model Power Park Economic Parameters**
- ◆ **To Develop Operational Envelopes For Optimized Power Park Models**
- ◆ **To Identify The Customer Value Proposition**

◆ **Total Project Funding = \$2,2426,979**

- **Contractor Funding = \$1,426,979**
- **DOE Funding = \$800,000**

◆ **Expenditures To Date = \$822,242**

- **2003 = \$553,401**
- **1st Quarter 2004 = \$268,841**

DOE TECHNICAL TARGETS

◆ Hydrogen Production By Electrolysis

- 2005 Total H_2 Cost = \$3.80/kg
- 2005 Energy Efficiency = 65%
- Electrolysis Cell Stack = \$0.48/kg
- Compression = \$0.32/kg
- Electricity = \$1.80/kg
- Power Conversion = \$0.28/kg





DOE TECHNICAL BARRIERS

◆ **Cost**

- **Electricity**
- **Hydrogen Fuel**
- **Production Equipment**

◆ **Efficiency**

◆ **Grid Emissions (Carbon Reduction)**

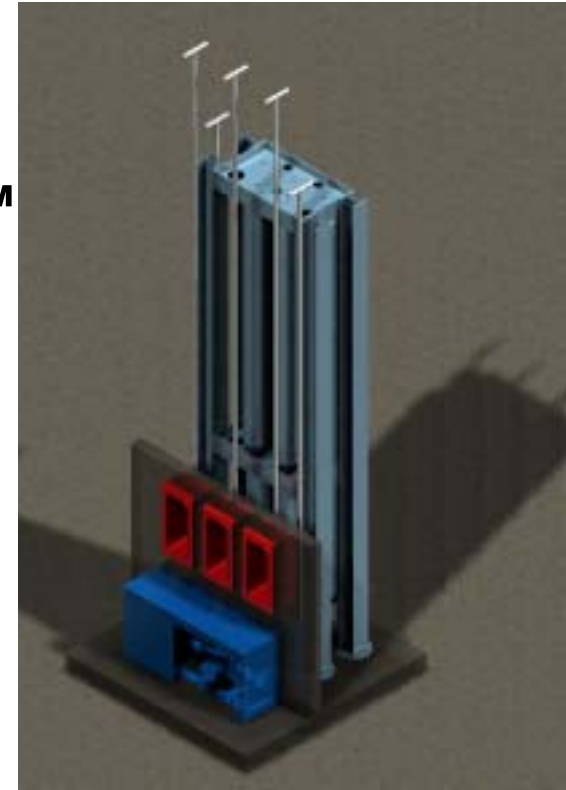
- **Generation Mix**
- **Renewable Integration**



TECHNICAL APPROACH

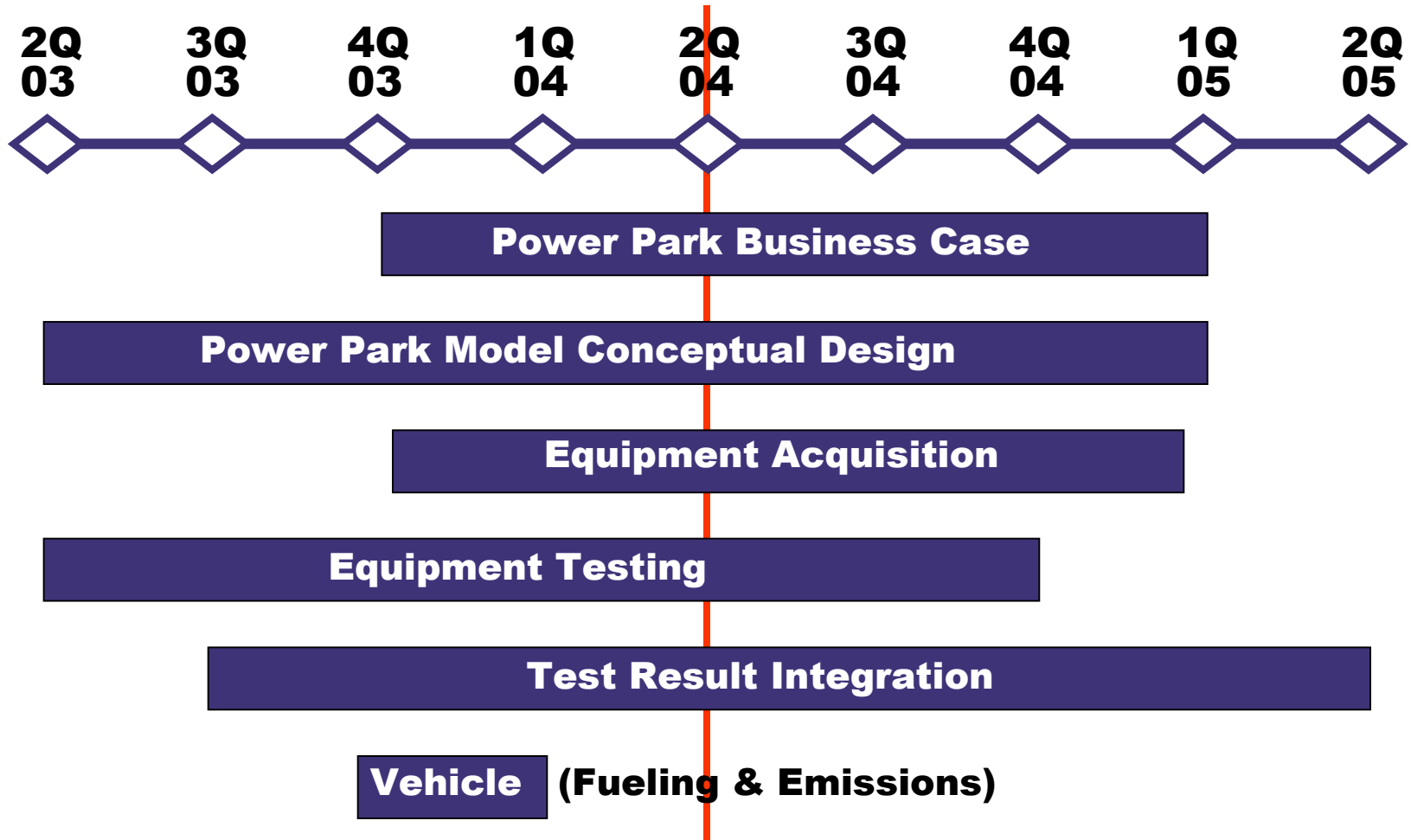
- ◆ **Develop Four Power Park Models Based On Current Knowledge Of Costs & Benefits**
- ◆ **Validate The Performance Of Each Model By Testing Of Components**
- ◆ **Analyze The Business Case For Each Power Park Model Using Actual Performance and Cost**
- ◆ **Value Engineer Each Power Park Model To Identify Opportunities To Improve Economics**
- ◆ **Identify System Operations for Opportunity**
- ◆ **Identify Customer Value Propositions**

- ◆ **Hydrogen Storage and Handling**
 - **Utilize Coaxial Containment System™**
- ◆ **Power Park Component Testing**
 - **Test Plans Include HAZOP Issues**
 - **Qualify Test Personnel**





PROJECT TIMELINE





KEY ELEMENTS OF THE POWER PARK

- ◆ **Renewable Energy Source**
- ◆ **Hydrogen Production**
- ◆ **Vehicle Refueling**
- ◆ **Electric Generation**



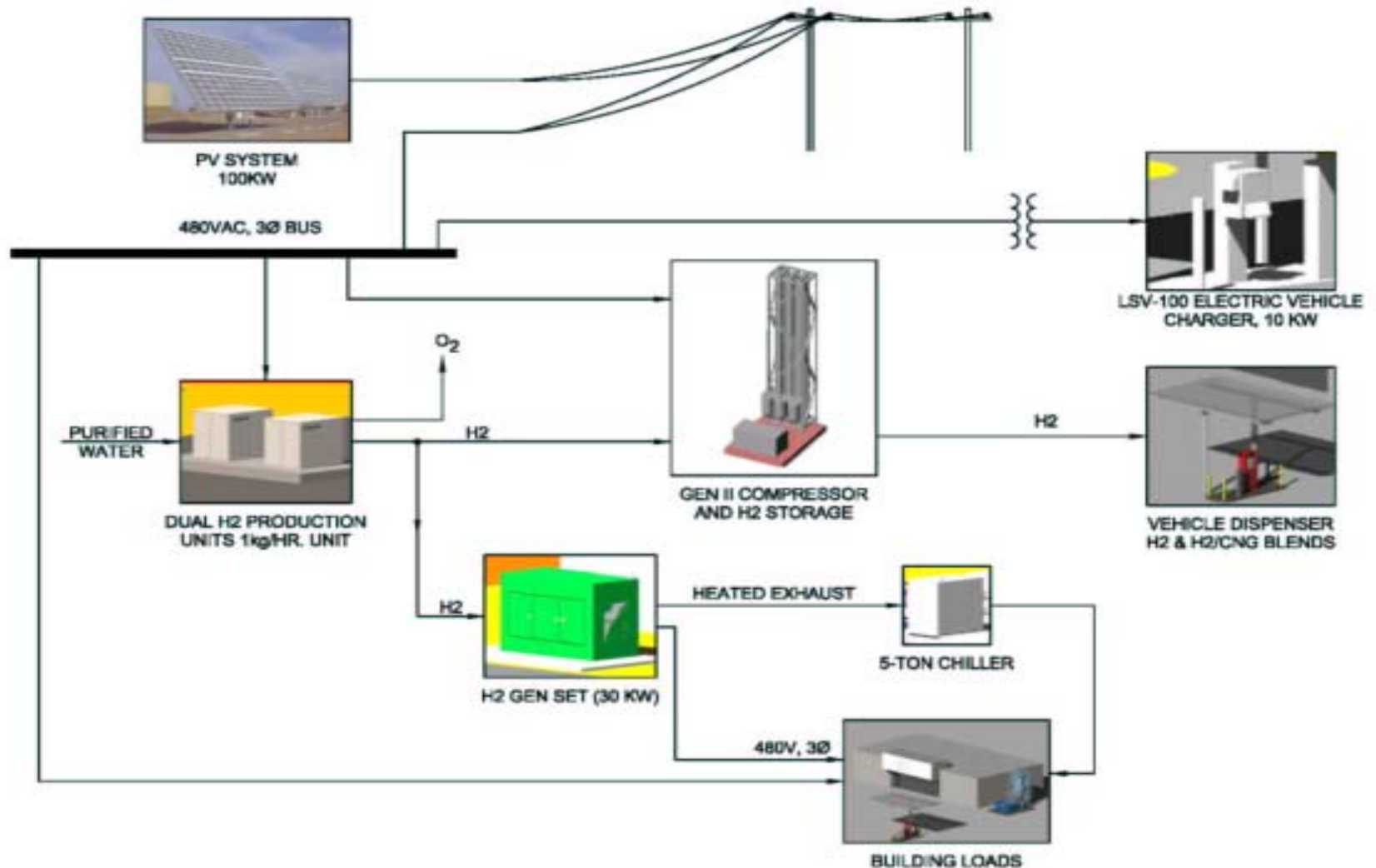
POWER PARK MODELS

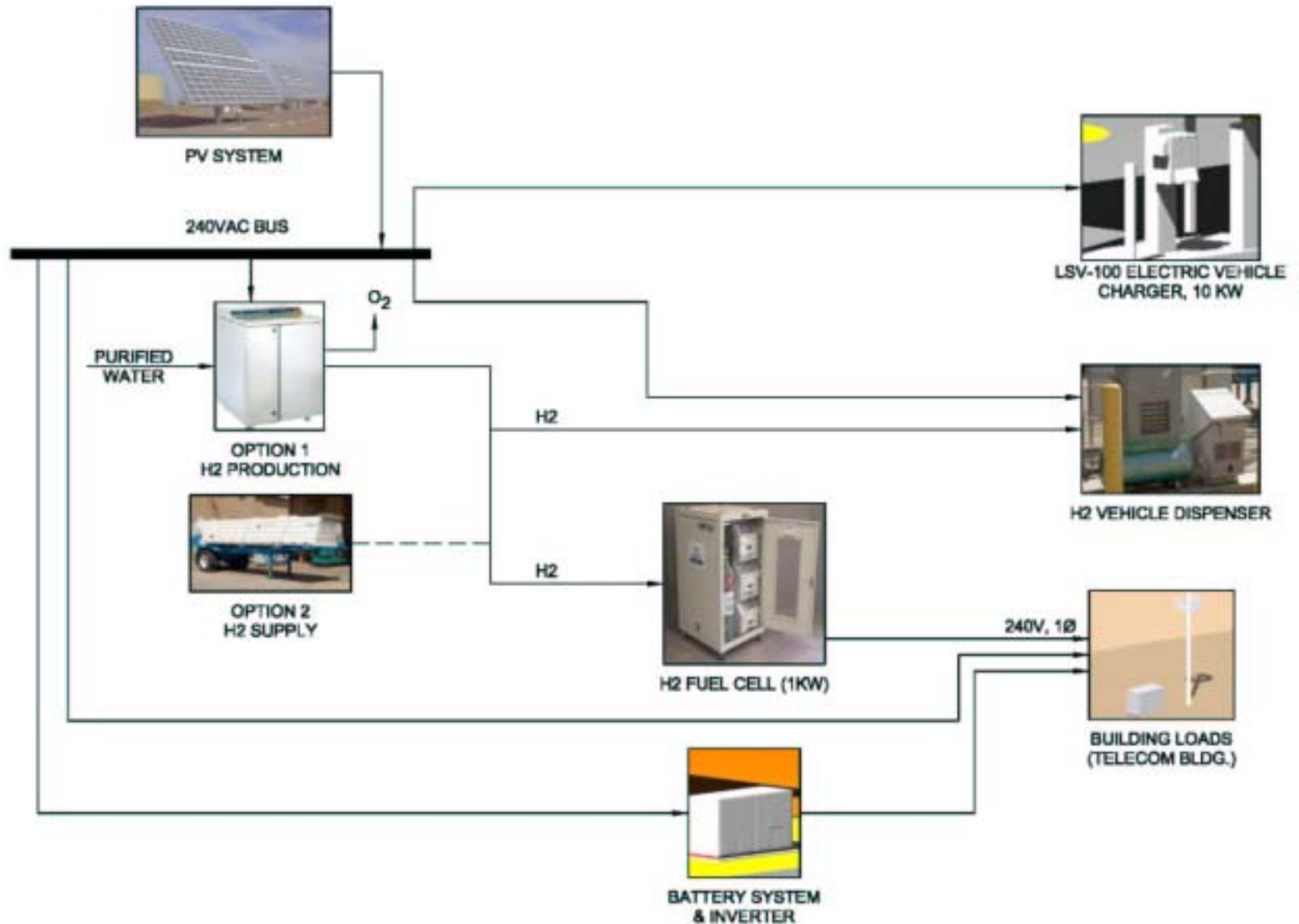
◆ Four Models Defined

- 50 kg/day Grid Connected**
- 4 kg/day RAPS/UPS**
- 1,500 kg/day Grid Connected**
- 150 kW Mobile**

◆ Use Existing Utility Assets

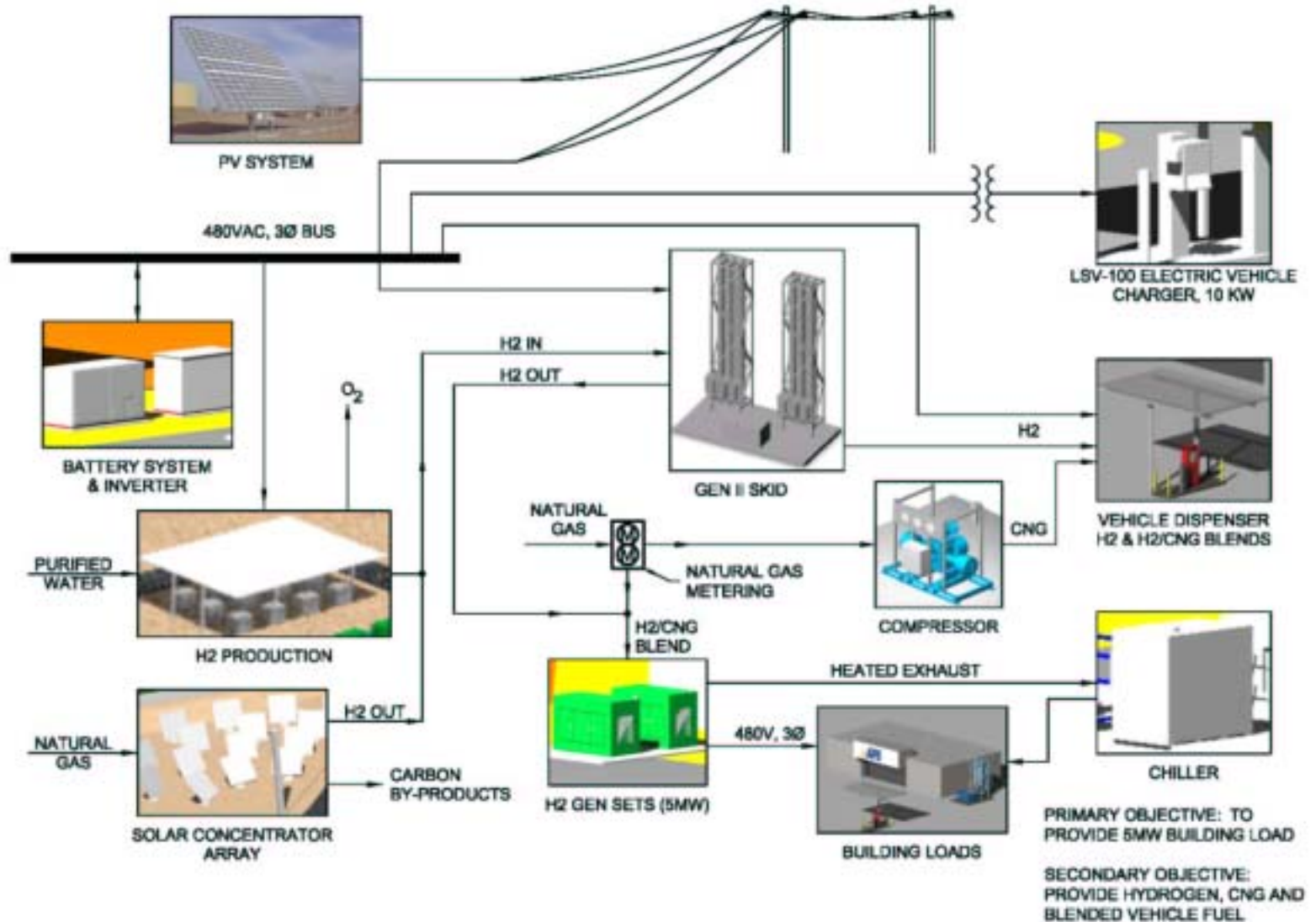
◆ Maximize Economic Value

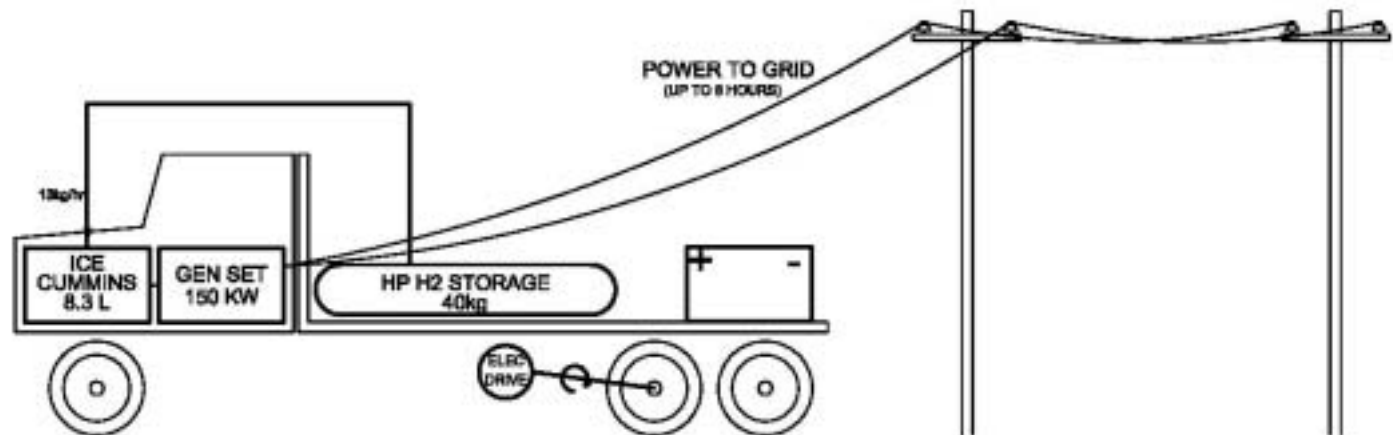






1,500 kg/day GRID CONNECTED





- HYBRID
- 480V 3Ø
- 208V 3Ø
- 240V 1Ø
- AVERAGE OF 22 MILES/DAY

PRIMARY OBJECTIVE:
TO PROVIDE 100kW OF
ELECTRICAL POWER

- ◆ **Control System – Installation Underway**
- ◆ **Hydrogen Production**
 - **Pilot Plant Operating**
 - **Acquiring Additional Electrolysis Equipment**
 - **Acquiring Increased Compressor Capacity**
- ◆ **Refueling Dispensers Installed and Operating**
- ◆ **Fuel Cells**
 - **Acquiring Proton Unigen - 1 kW**
 - **Acquiring Plug Power backup power – 5 kW**
- ◆ **ICE**
 - **5.4L low and high boost**
- ◆ **ICE Genset**
 - **70 – 125 kW with NG, HCNG, & H₂ Fuel**
 - **11 kW with propane and H₂ Fuel**
- ◆ **Chiller**
 - **Acquiring 5 ton chiller with waterless cooling**
- ◆ **Line Truck**
 - **Acquiring Class 8 Utility Line Truck**
- ◆ **Renewable Energy**
 - **7 kW PV Array Installed**

◆ **Hydrogen**

- **Production by Electrolysis (Proton)**
- **Commercial Delivery**

◆ **Vehicle Refueling and H₂ Storage/Handling**

- **CNG, CHyNG, Hydrogen (6,000 psi)**
- **2,350 fueling events**

◆ **Vehicle ICE Emissions**

- **Blends 15%, 30%, 50%**
- **Hydrogen**

◆ **Vehicle ICE Performance**

- **Blends 15%, 30%**
- **Hydrogen**





APS WEBSITE



THE POWER TO MAKE IT HAPPENSM

Hydrogen Power Park

[H2 pilot plant
Control panel](#)

[Pilot plant
analysis](#)

[APS renewable
energy
Plants and
production](#)

Energy efficiencies and cost of renewable energies can be monitored in real time through acquisition systems now web-based. We can monitor hydrogen production and storage, as well as, doing analysis with data recorded in the last six months.

Currently, Arizona Public Service has photovoltaic generation capacity of over 5 megawatts.



Pilot hydrogen plant and refueling station

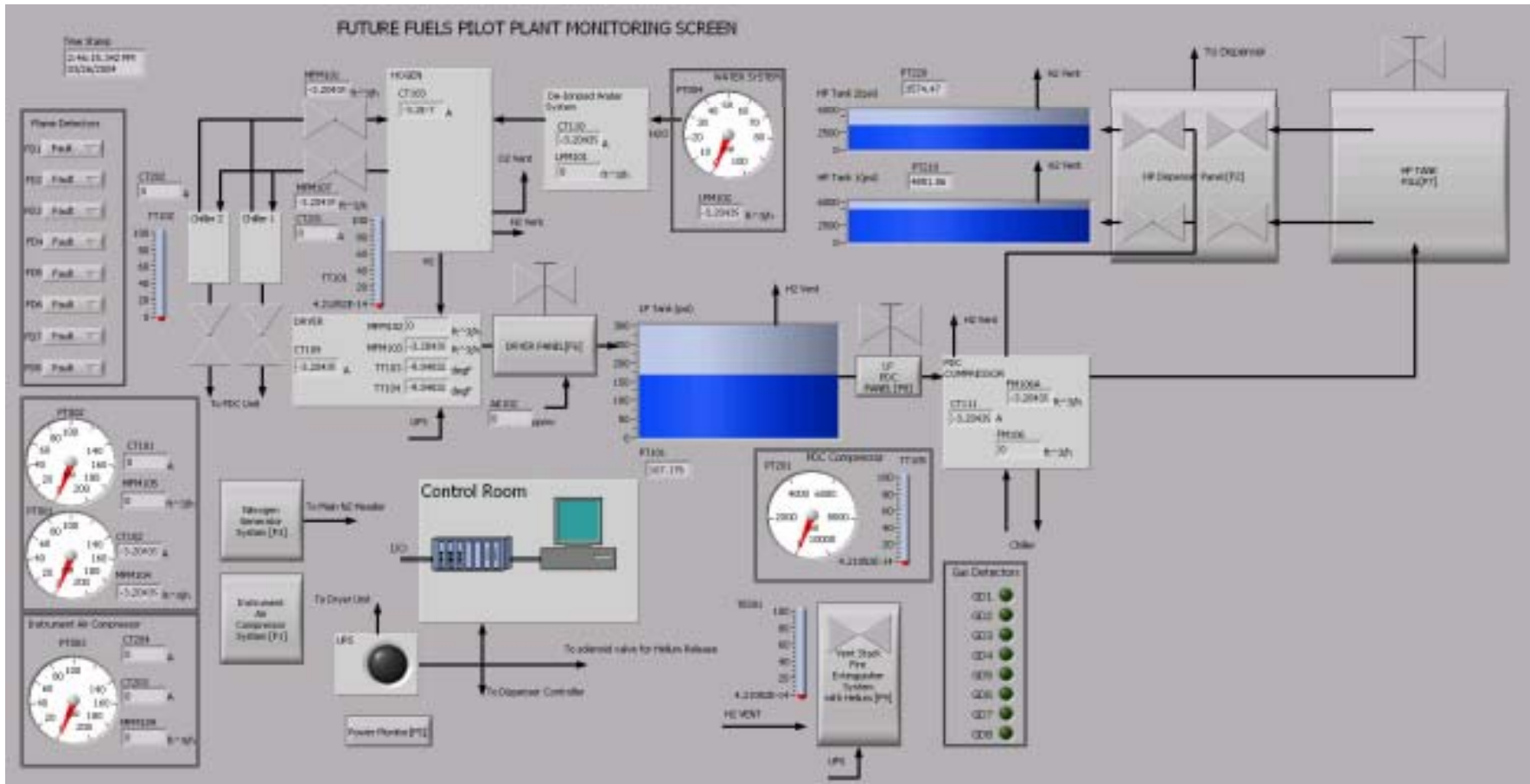
Hydrogen production from water electrolysis.

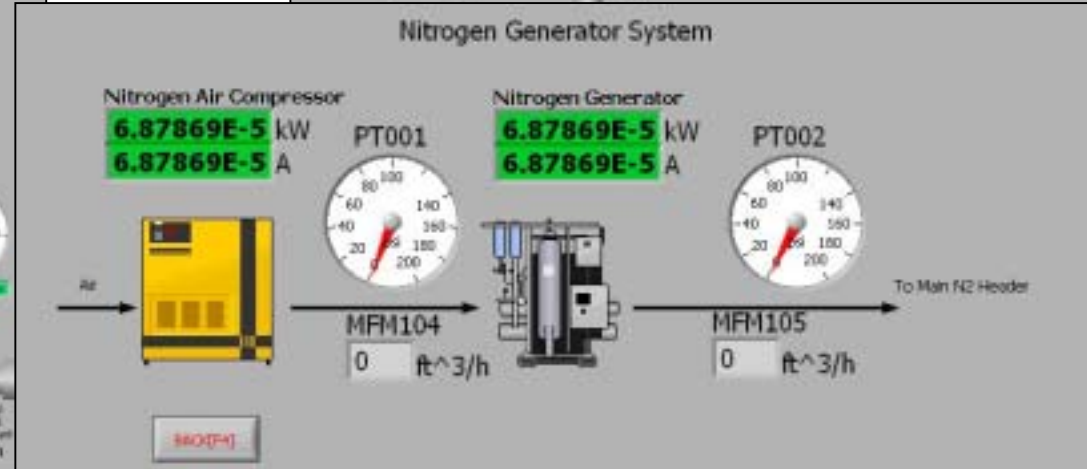
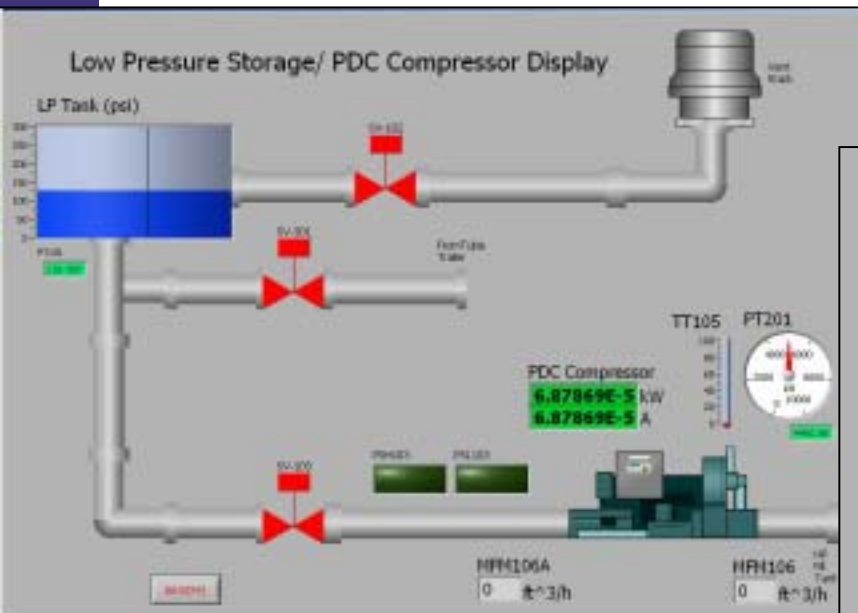
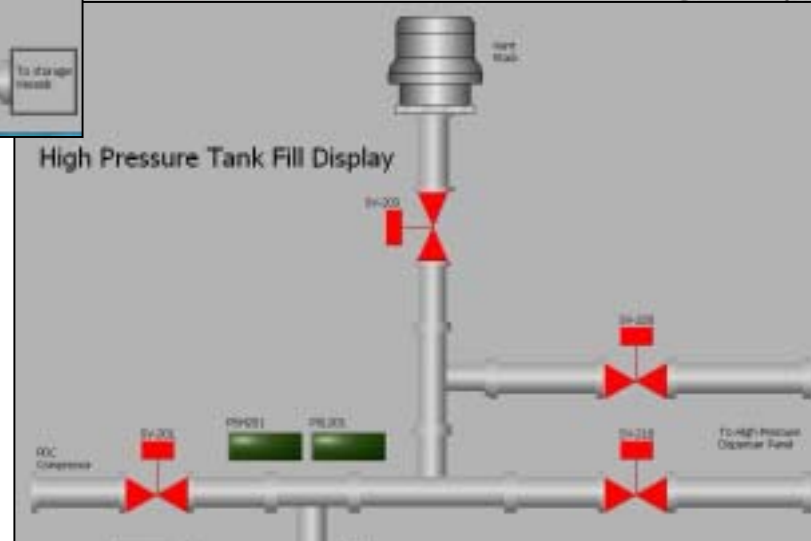
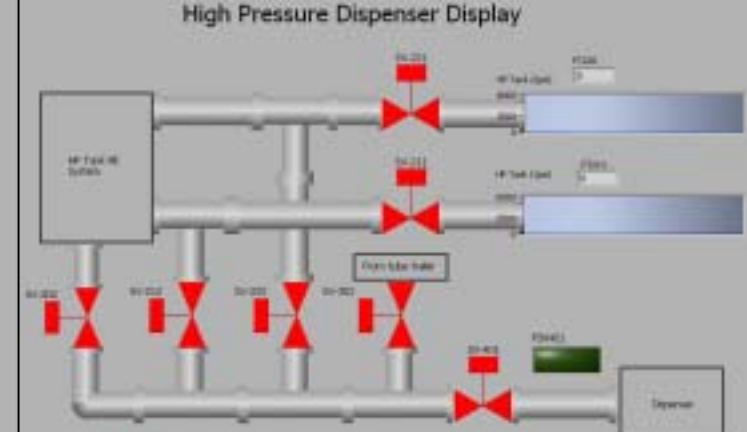
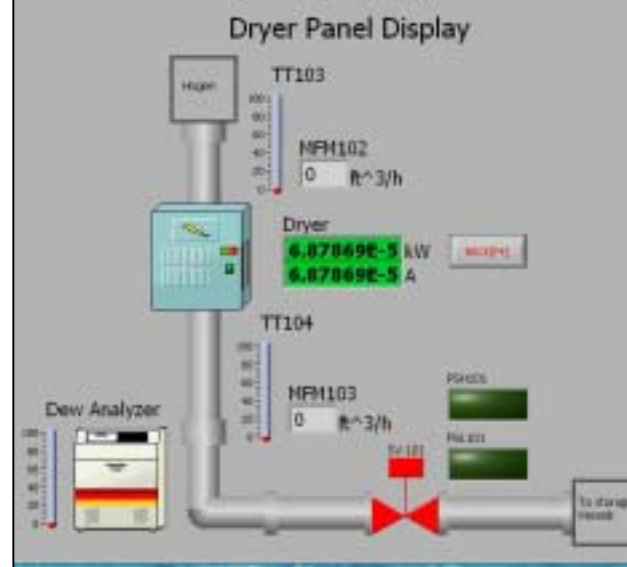


H2-Fueled Distributed Electric Generation



Internet Site Accessible





CONTROL SUB-PANELS



TESTING – DISTRIBUTED GENERATION

ICE Hydrogen & Blends

- ◆ **Renewable Energy**
 - **Solar Data Collection Underway**



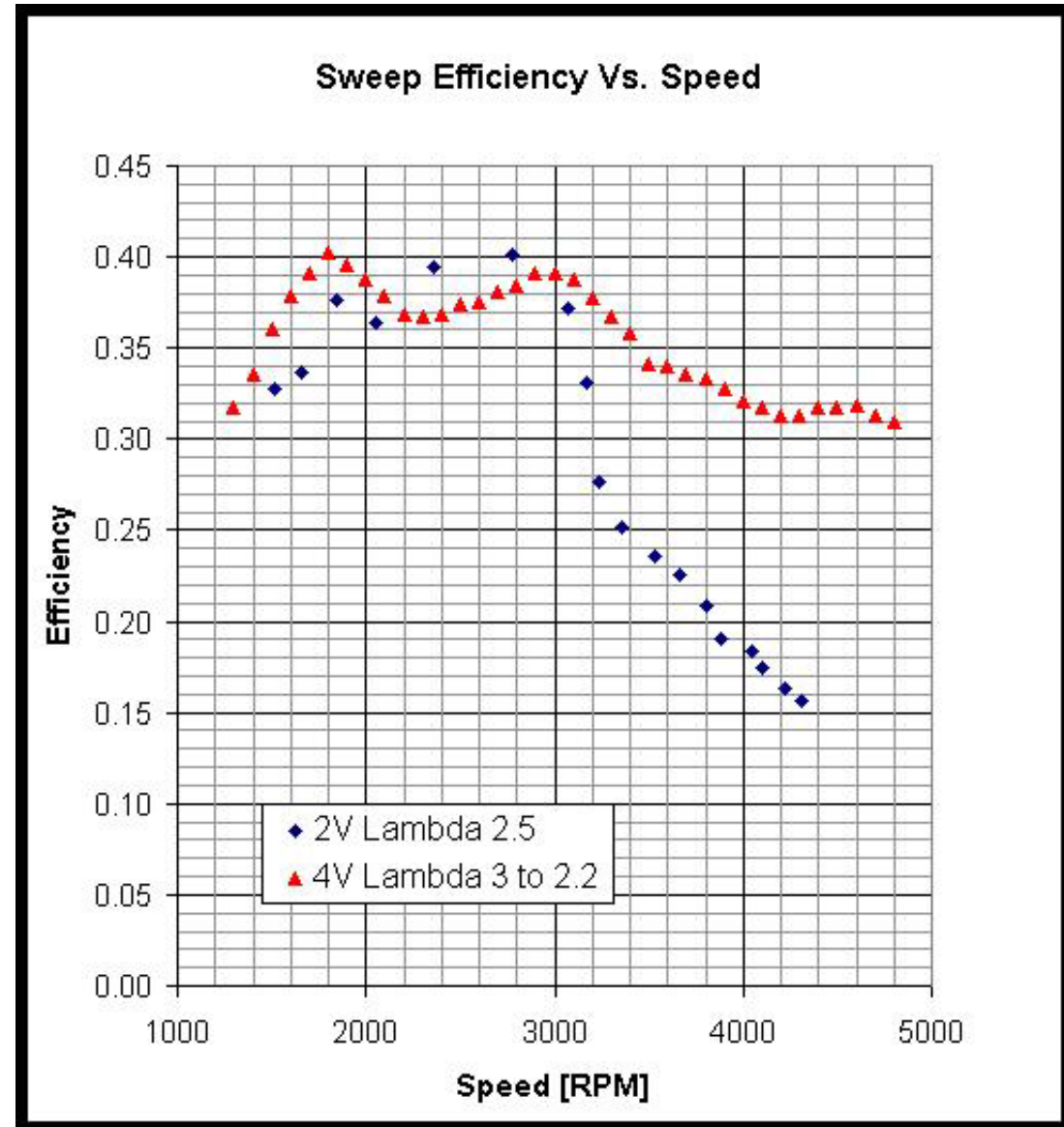
- ◆ **Power Generation**
 - **5.4 L ICE – (H₂ & Blend) Complete**
 - **11 kW H₂ ICE & Propane - Complete**
 - **8.3L Cummins ICE – (H₂ & Blend) Underway**

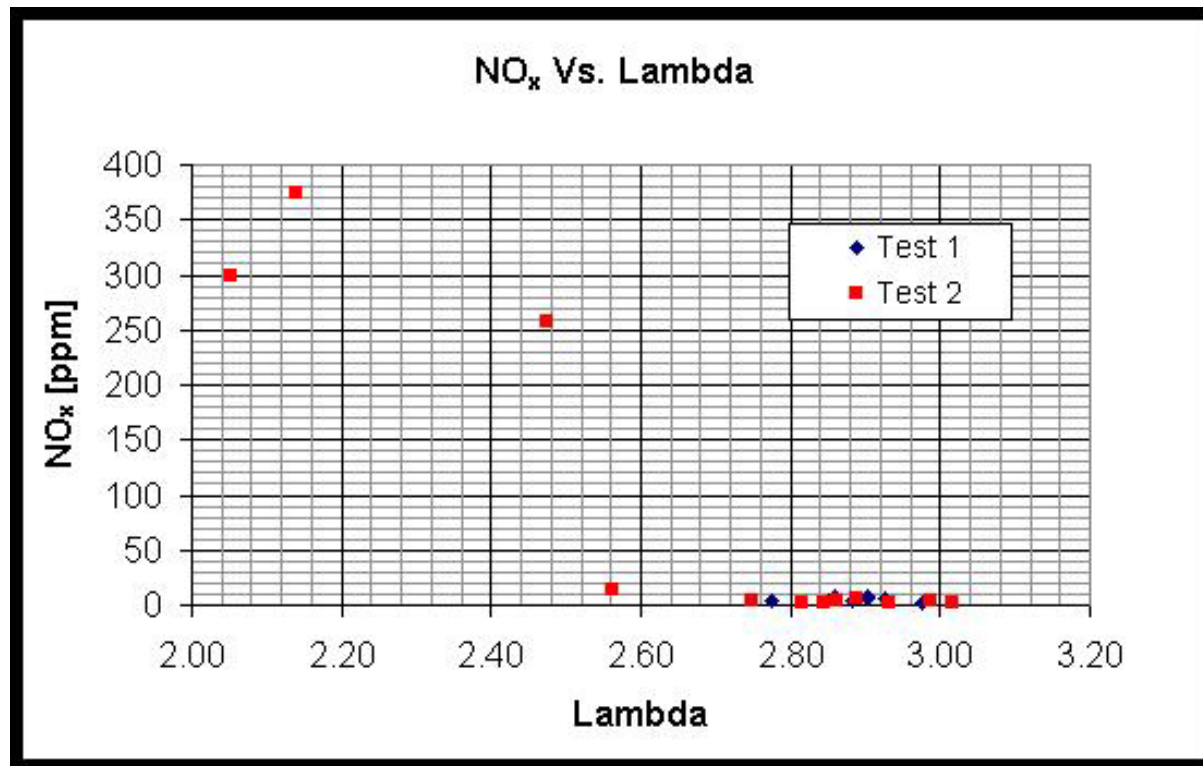


TESTING - ICE

ENGINE PERFORMANCE 5.4 L - Complete

- ◆ **Hydrogen Fuel**
- ◆ **High Efficiency Achieved**
 - **High Compression Ratio**
 - **Fuel Ratio & Spark Timing Critical**
 - **Tradeoff With Power & Emissions**





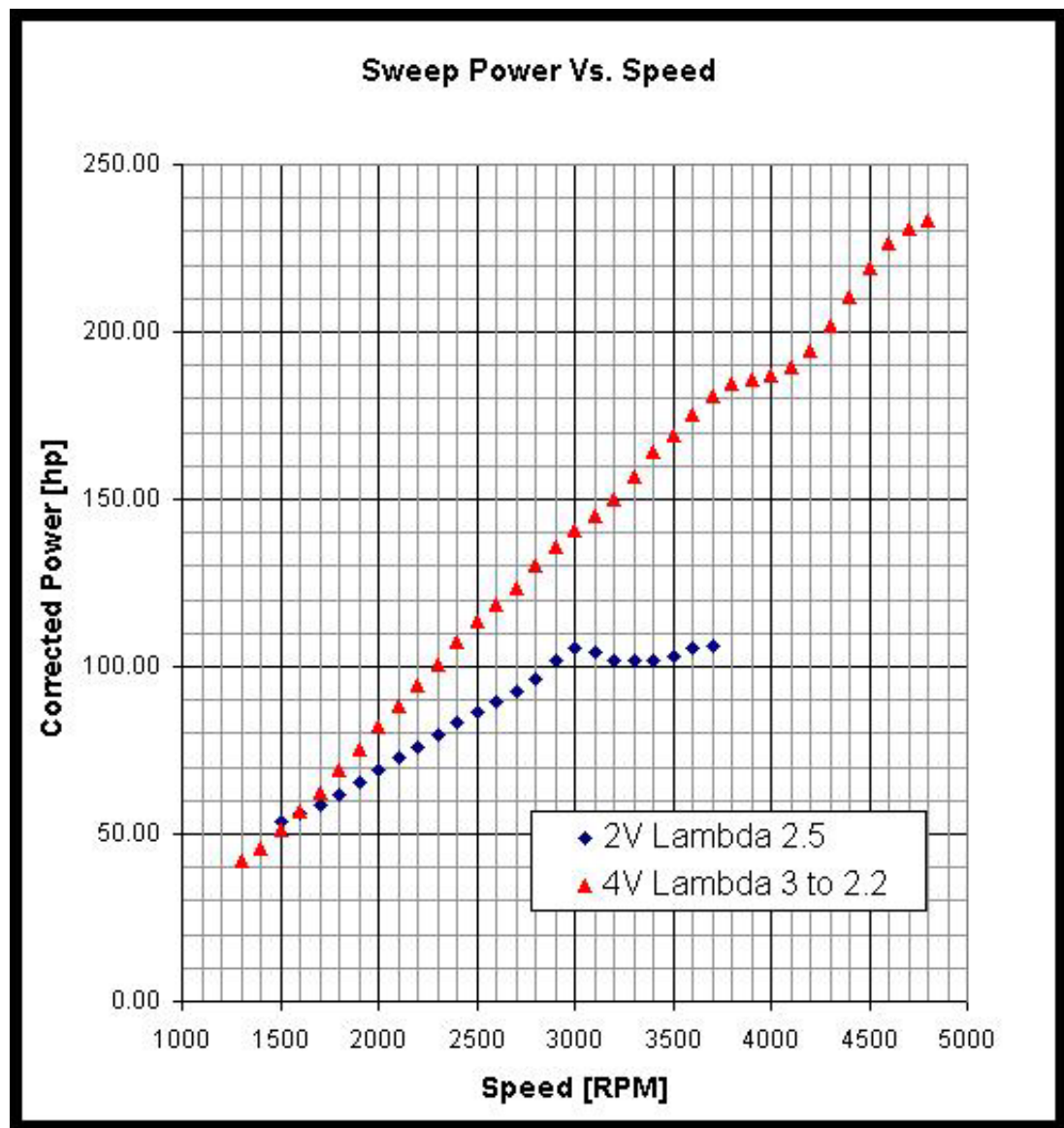
- ◆ **Hydrogen Fuel**
- ◆ **Emissions Sensitive To Fuel Air Ratio**
 - **Tradeoff With Power**
 - **Forced Induction Replaces Lost Power**
 - **Insignificant Emitter**



ENGINE PERFORMANCE

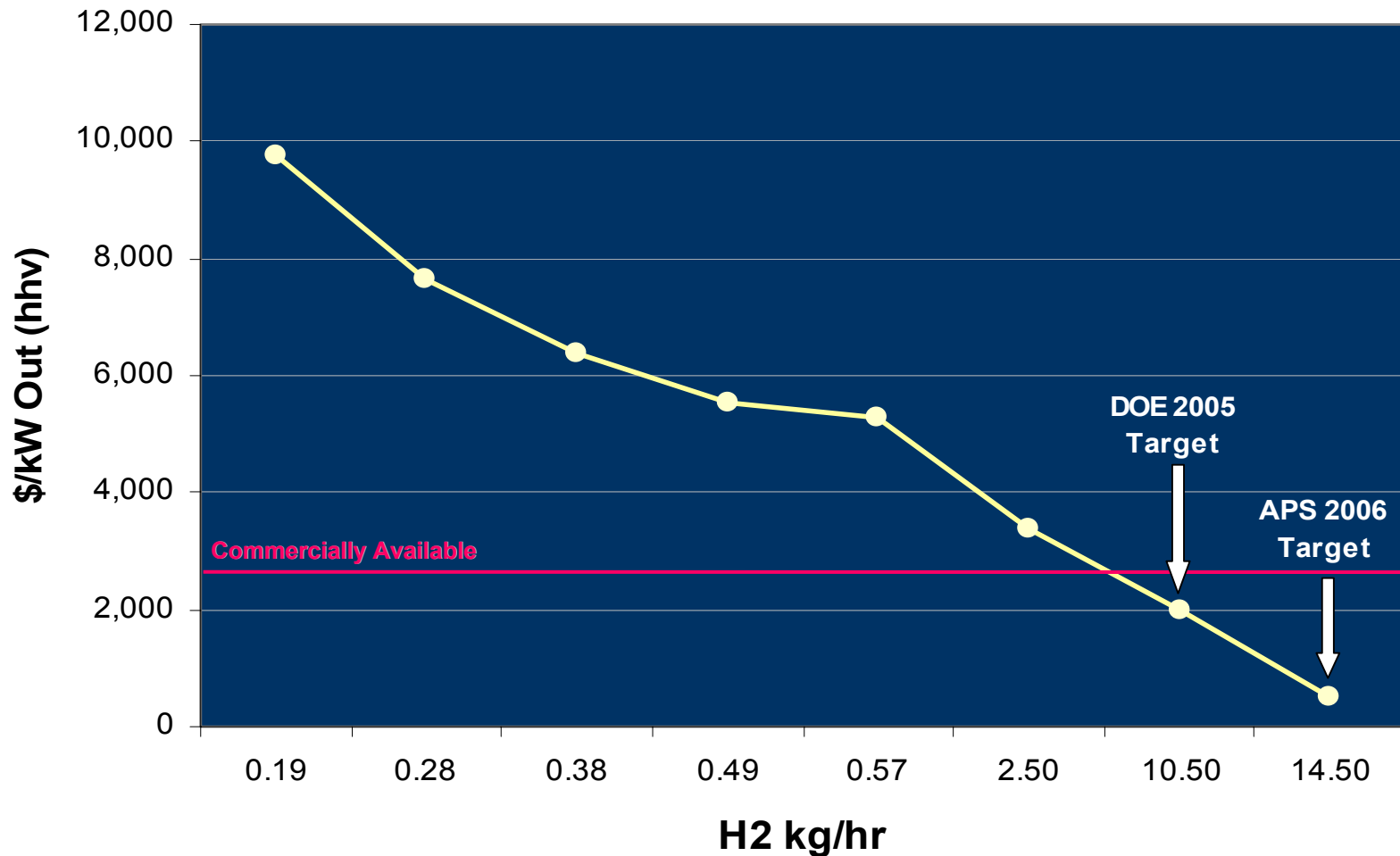
5.4 L (continued)

- ◆ **Hydrogen Fuel**
- ◆ **230 hp 5.4L**
 - **13.5 psi Boost**
 - **12.5:1 CR**
 - **Low ER**
- ◆ **110 hp 5.4L**
 - **4.5 psi Boost**
 - **13.7 CR**
 - **Low ER**



Electrolyzer Equipment Costs

Hydrogen Production Rate vs. Electrolyzer Cost





INTERACTIONS & COLLABORATIONS

- ◆ **BC Hydro, Canada**
Power Park Models, High Pressure Storage
- ◆ **Southern California Edison, California**
Battery Systems, Hybrid Power Train
- ◆ **General Electric, New York**
Hydrogen Production
- ◆ **Publications**
Hobbs, R.S., “Development of Hydrogen Fuel Based Power Park”: Proceedings of the 15th Annual National Hydrogen Association Conference, April 26-30, 2004, Hollywood, California.

◆ **Comments**

- **Project Not Started**
- **No Accomplishments Noted**
- **Need Additional Detail**

◆ **Resolution**

- **Contract Executed Through The State Of Arizona**
- **Measurable Progress Presented**

◆ **Complete Equipment Testing**

- **Electrolysis Unit**

- **Electrolyzer**

- **Fuel Cell**

- **UNIGEN PEM (1 kW)**

- **Plug Power (5 kW)**

- **Engine Generators**

- **8.3L Hydrogen 100 kW**

- **8.3L Natural Gas/Hydrogen Blend 100 kW**

- **Absorptive Chiller**

- **5 ton**

- **Engine Waste Heat Recovery**

◆ **Evaluate Power Park Models**

- **Integrate Test Results With Models**
 - **Determine Efficiency & Cost Based On Component Test Results**
- **Compare Costs To Alternatives**
- **Prepare Energy & Mass Balance for each model**
- **Finalize Conceptual Designs for Models**
- **Evaluate Business Case**
 - **Analyze Current Competitiveness**
 - **Evaluate Improvements Required To Achieve Competitiveness**
 - **Identify Equipment Cost & Operation Envelope**
 - **Identify Customer Value Proposition**